Proof of Concept Investigation of Active Velcro For Smart Attachment Mechanisms

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Department of Mechanical Engineering
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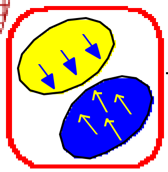
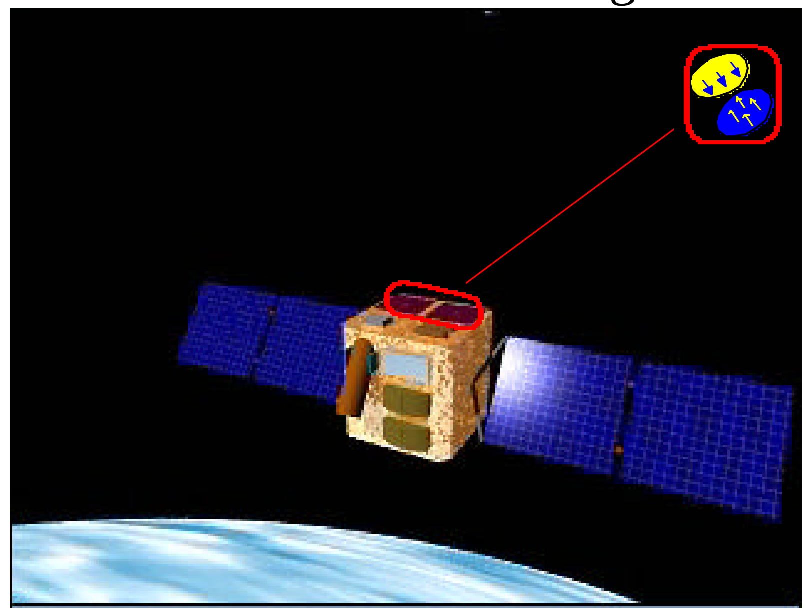
Motivation

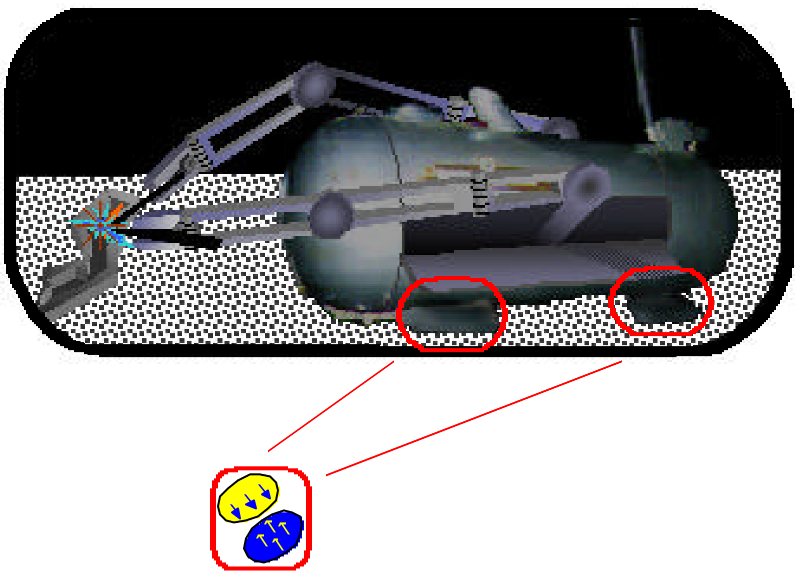


Smart Attachment Mechanism

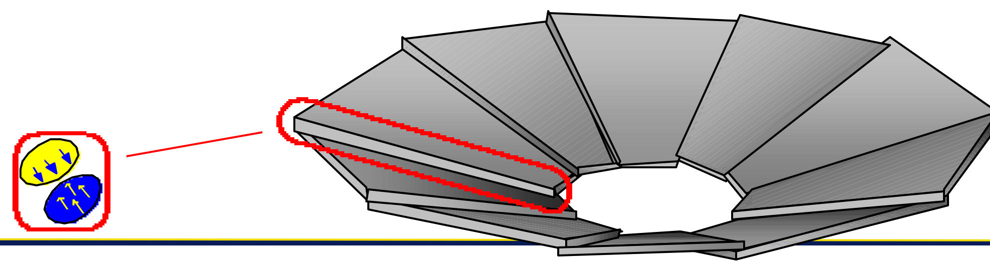
Autonomous docking



Locomotion along host satellite



Shape control for large deployable objects



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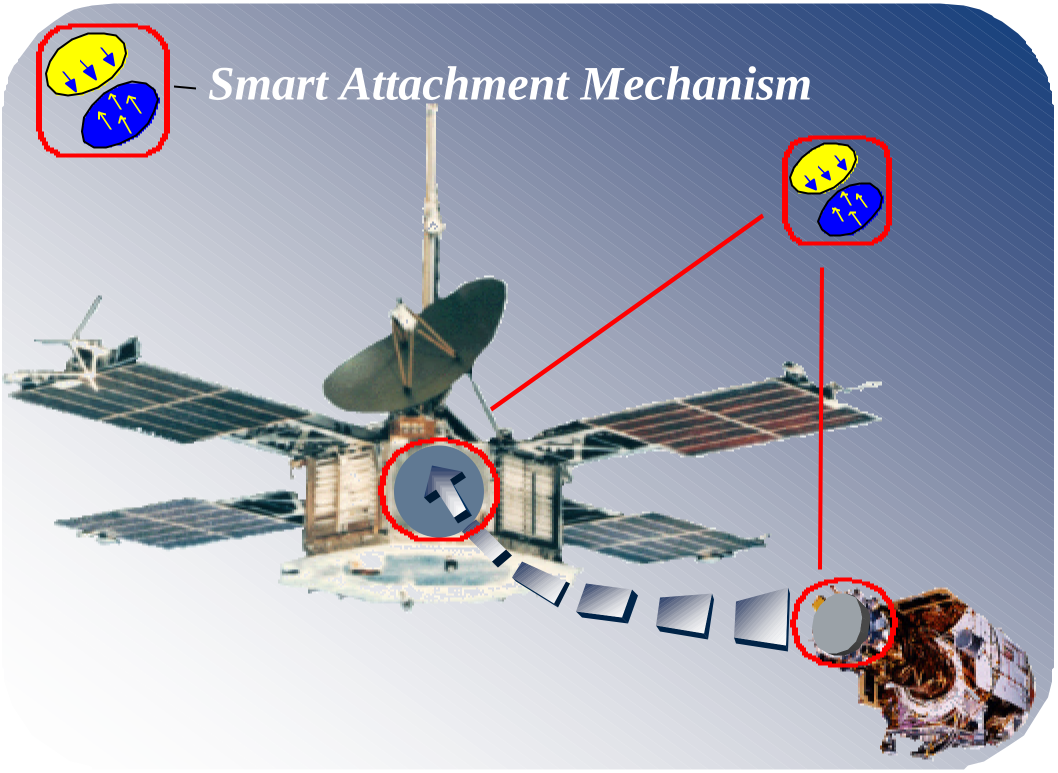
Active Velcro for Autonomous Satellite Docking

Goal: Develop an active surface capable of autonomously docking two orbiting satellites with precise position and orientation control.



Potential Benefits

Micro-Satellite

- reduced cost / weight
- reduced volume
- reduced complexity (navigation, guidance, homing, etc)

Host Satellite

- mission adaptability
- extended service life
- maintenance/repair facilitation
- module upgrade ability

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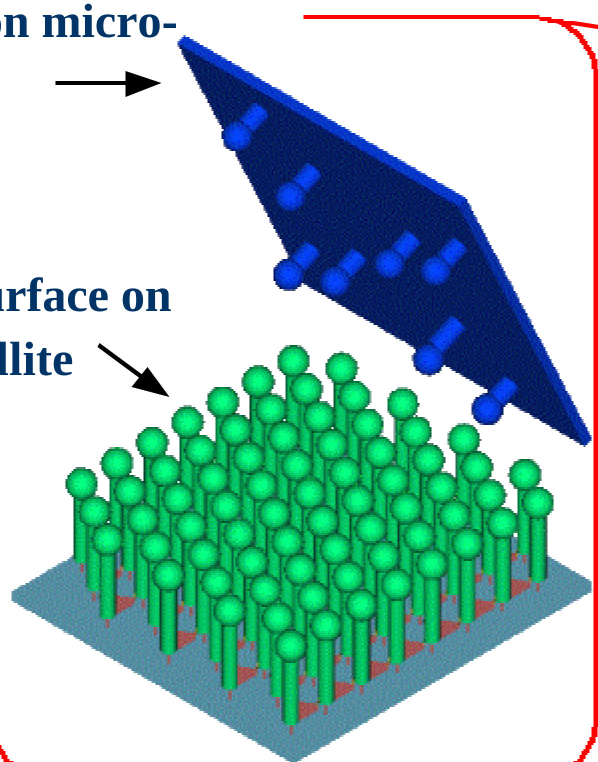
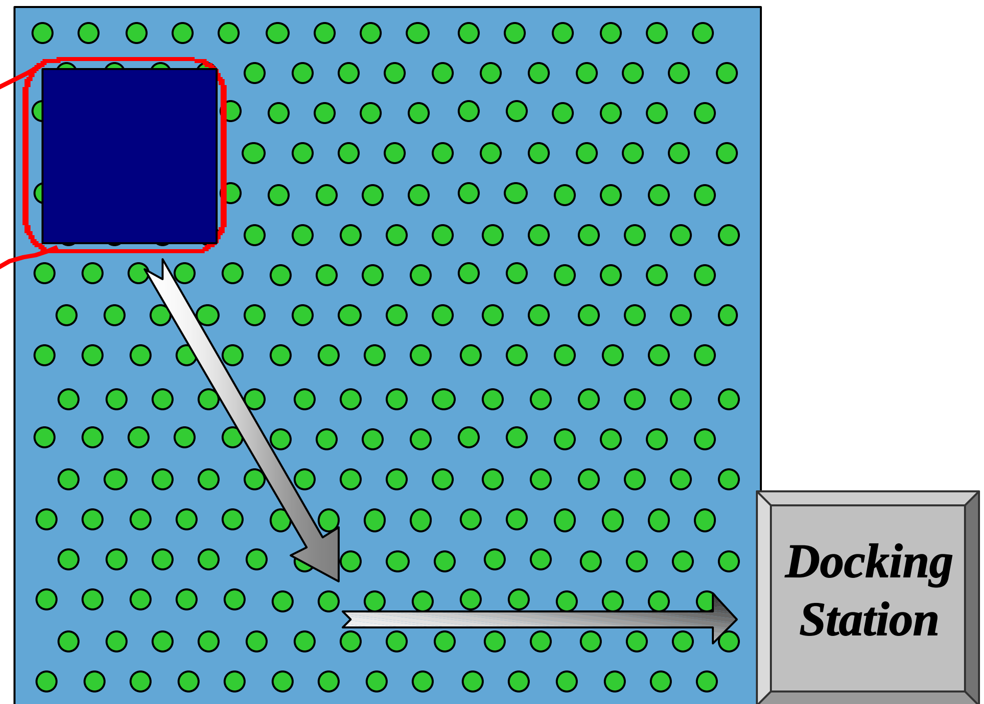
Active Velcro Overview

- The two surfaces passively *latch* on to each other like Velcro in contact.
- The SMA activated prongs on the active velcro surface inch the micro-satellite along the surface of the host satellite to dock.

Lightweight, passive surface on micro-satellite

Active surface on host satellite





Active velcro surface on host satellite provides a large target area for engagement

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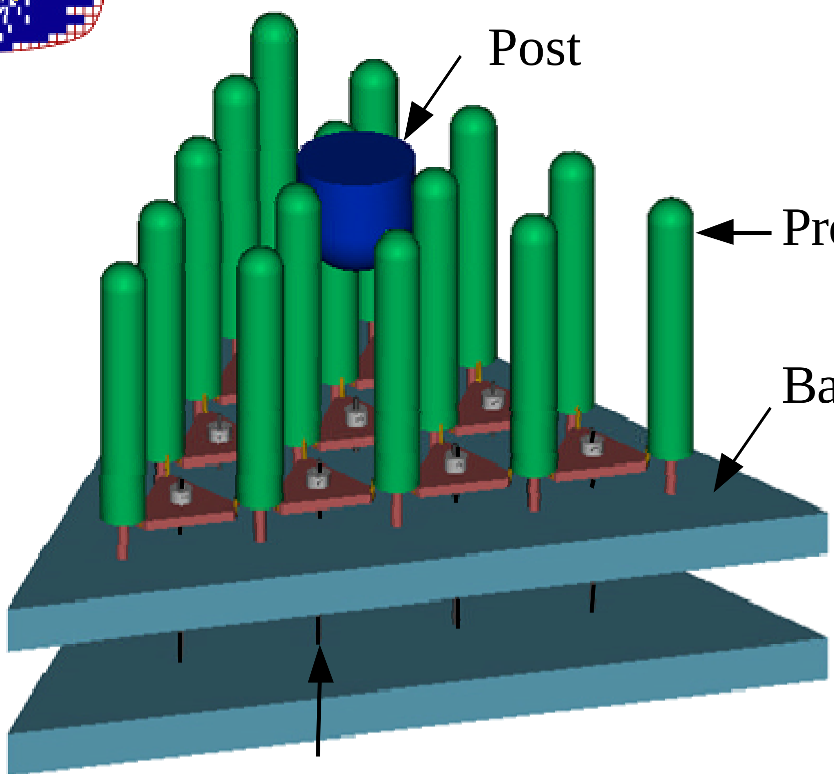
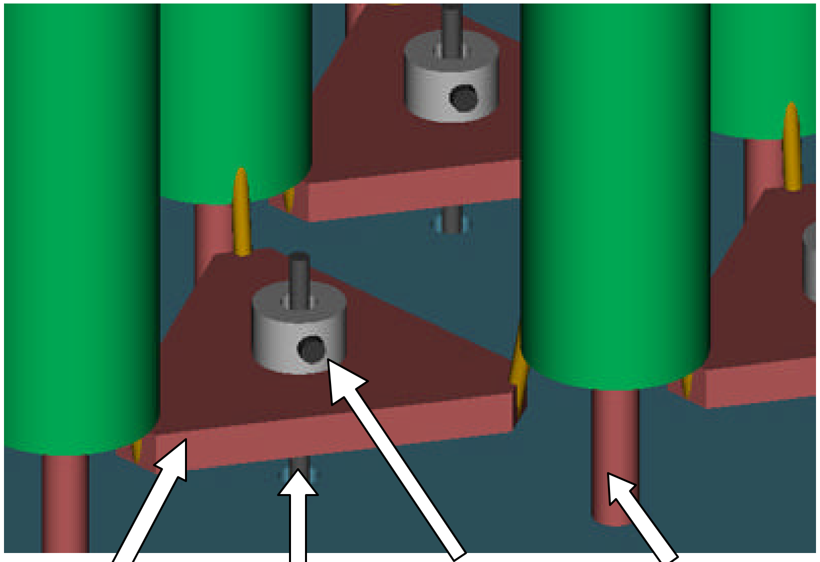
SMA Actuated Active Velcro Surface*





Flexure Mechanism Close-up

*Retention topology omitted for clarity

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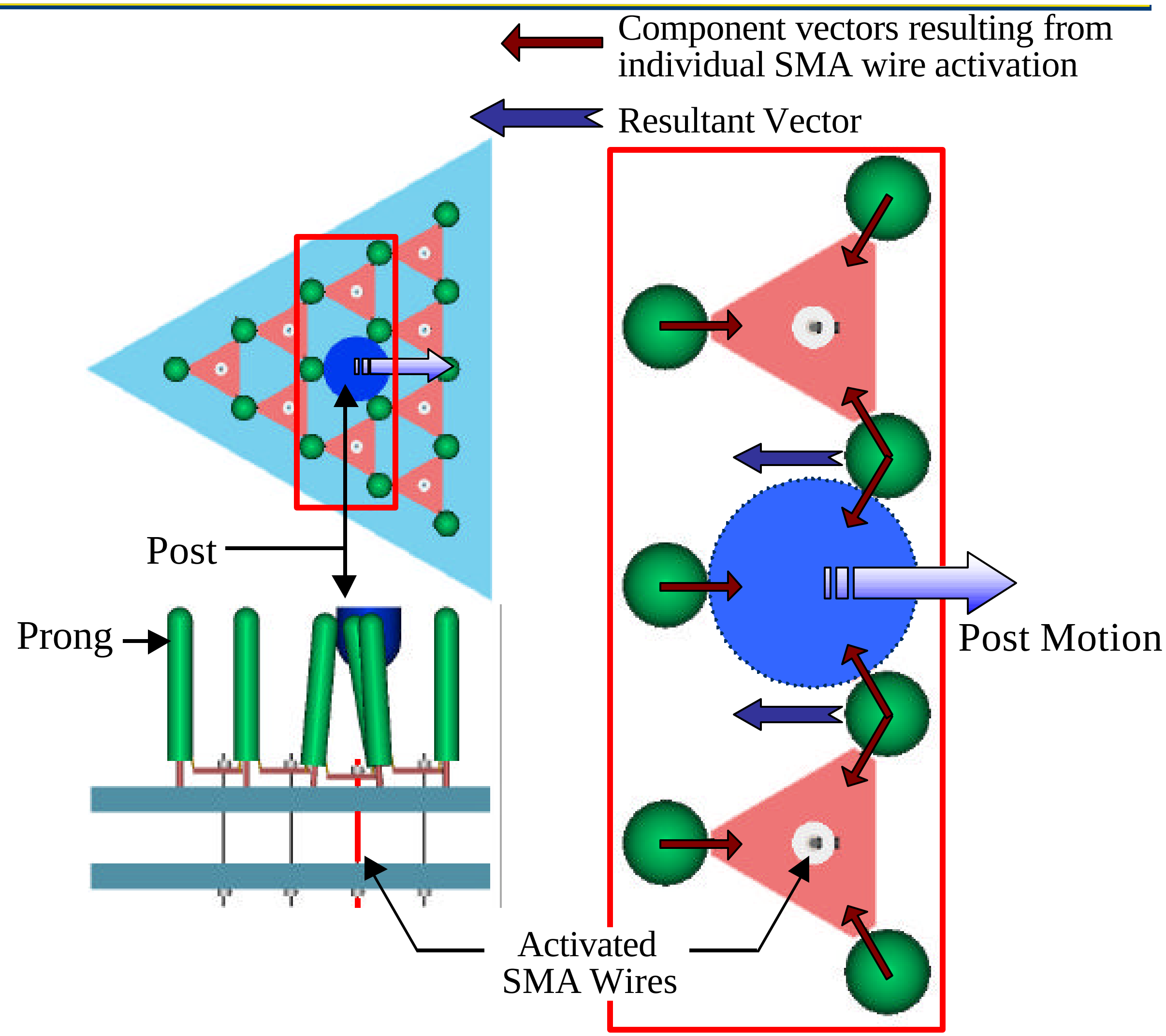
Local Prong Operation

- Activating a single SMA wire causes the three adjacent prongs to bend inward toward the center of the grouping.
- When adjacent SMA wires are activated, the resultant ( ) prong motion creates a path for the advancing post.



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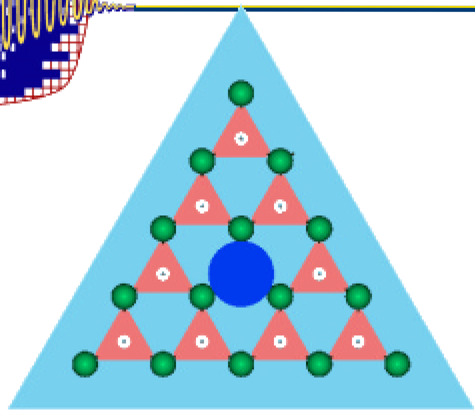
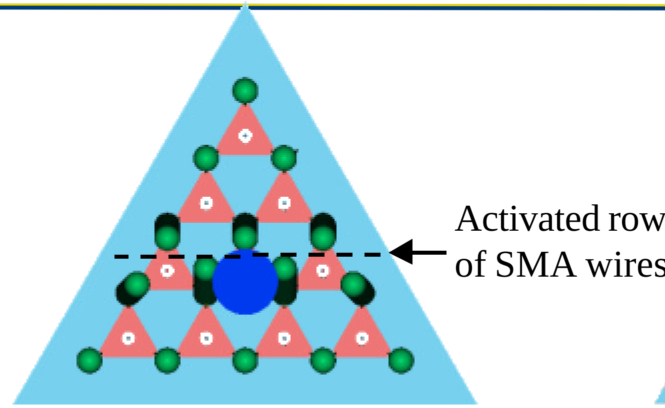
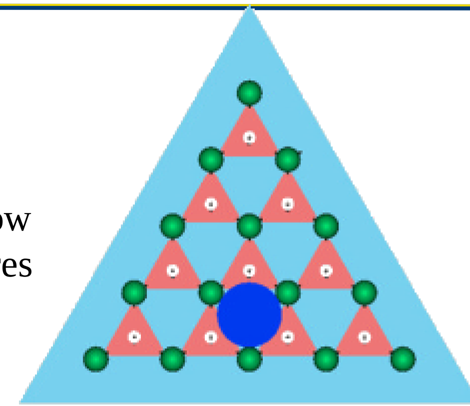
System Operation



Position 1



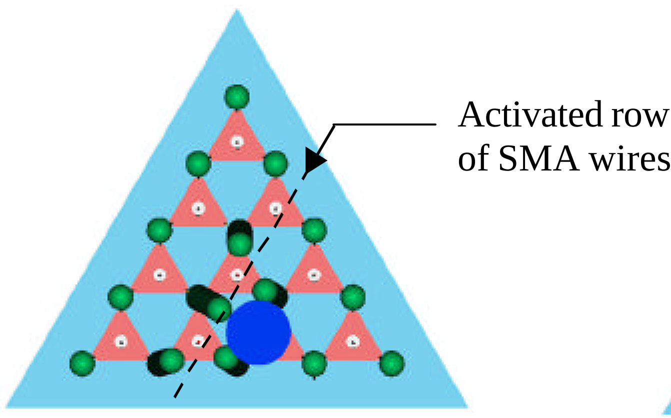
Mid-Translation 1-2



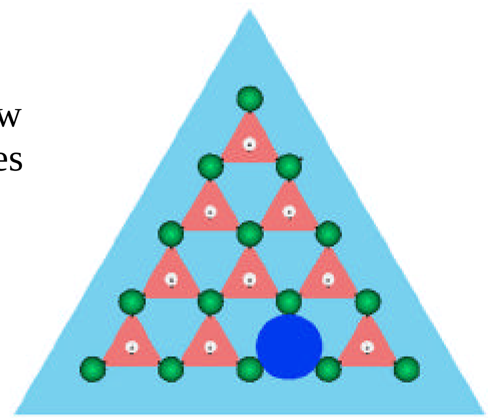
Position 2

Unactivated surface

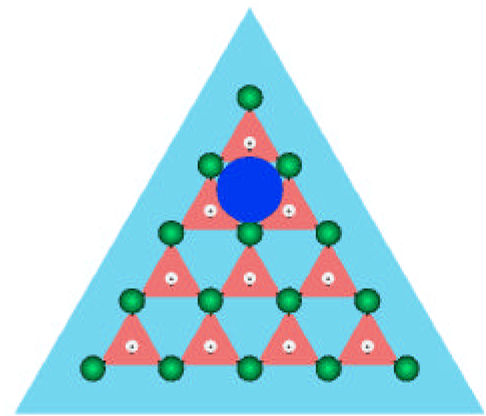
Activated row of SMA wires pushes post into next position



Mid-Translation 2-3



Position 3



Simulation

A different row of SMA wires is activated to advance post into next position

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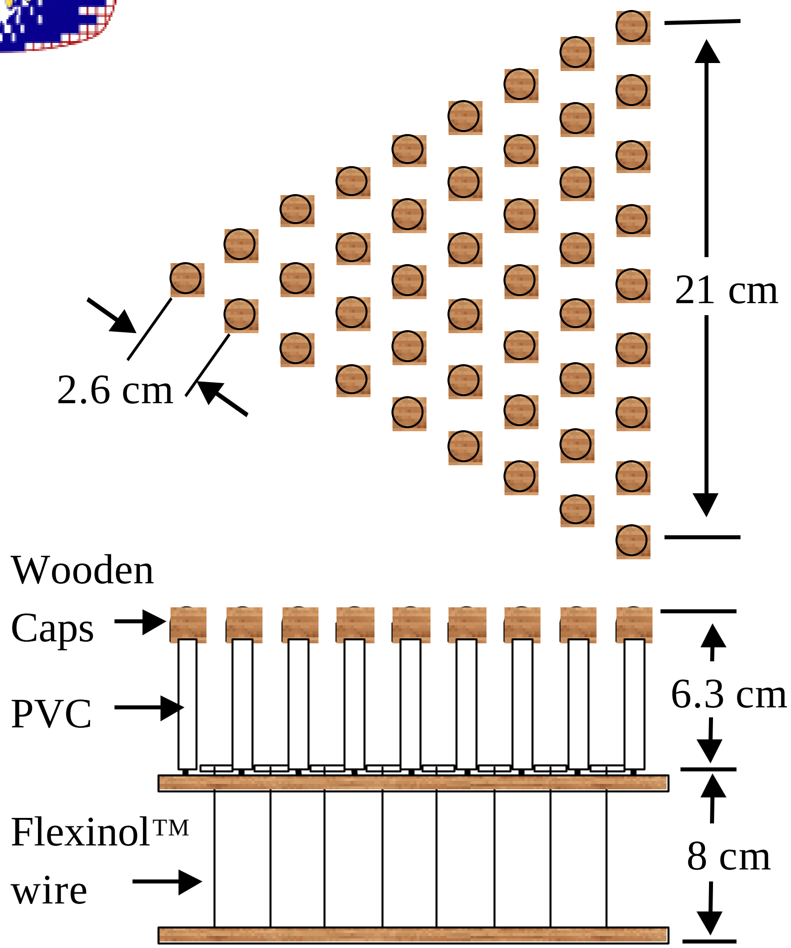
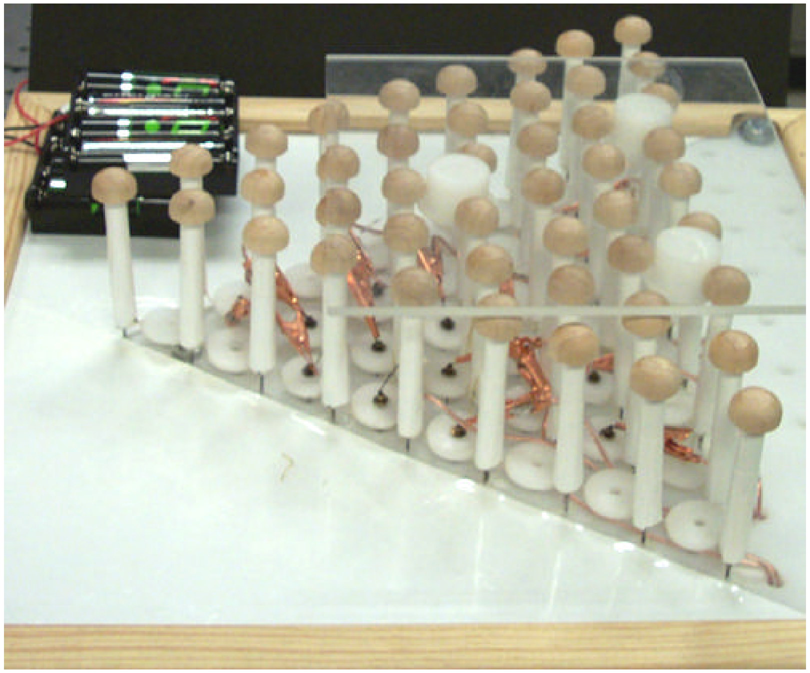
Large-Scale Prototype





Step Size: 15 mm
Linear Speed: 1.5 - 15 mm/s
Input Power (per step) : 3.3 W
Demonstrated Translation: 1 Post : 8 steps
3 Posts : 2 steps

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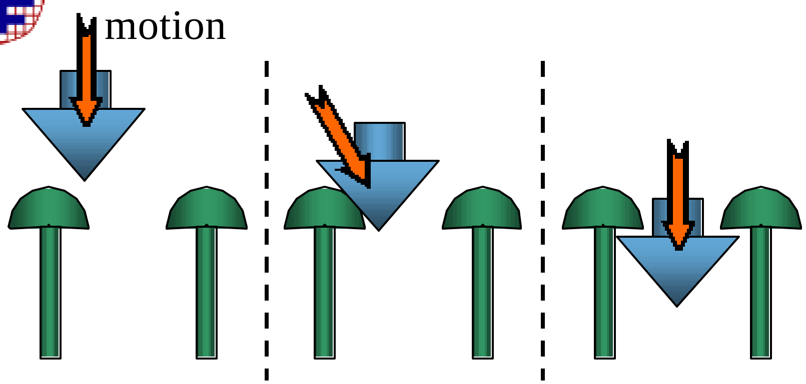
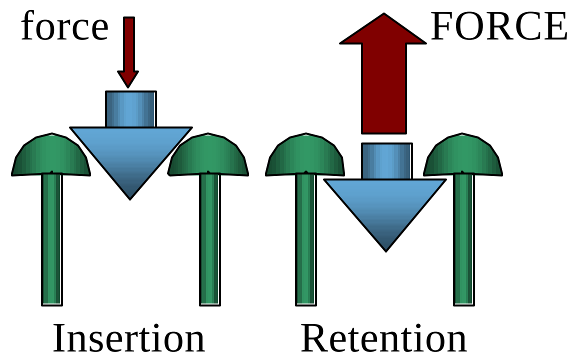
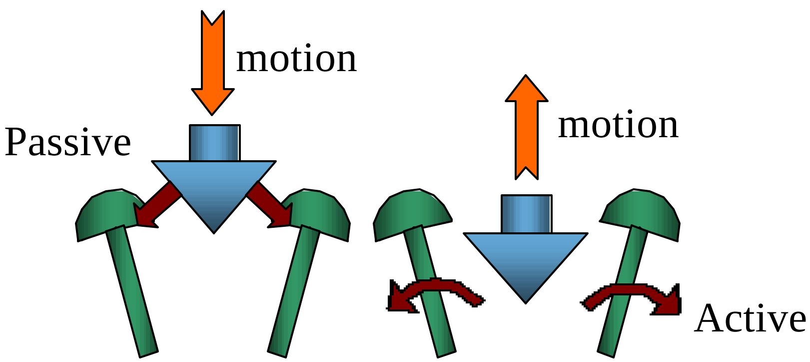
Topology Goals



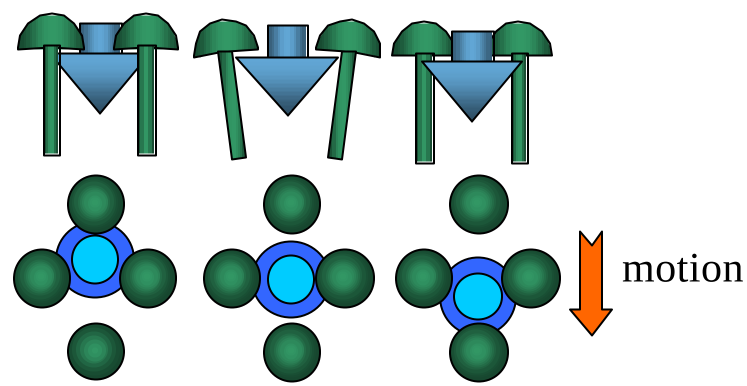
Guides in posts



Minimum insertion force / Maximum retention force



Passive engagement / Active disengagement



Enables motion (translation, rotation)

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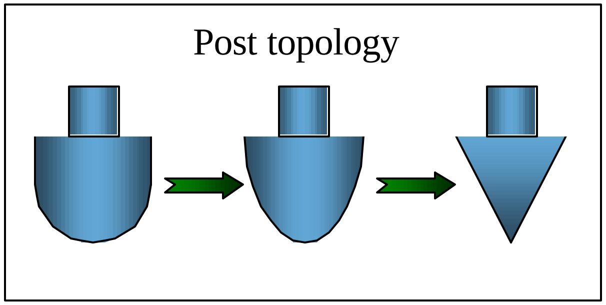
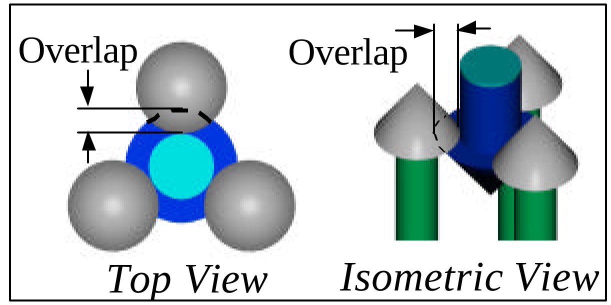
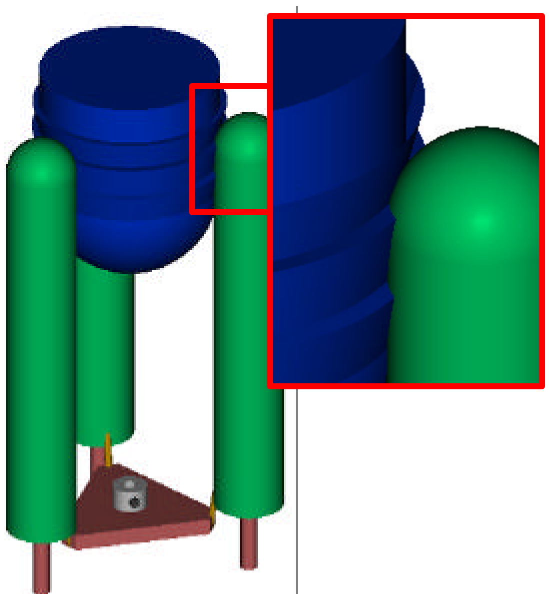
Retention Topology Concepts

Guidance

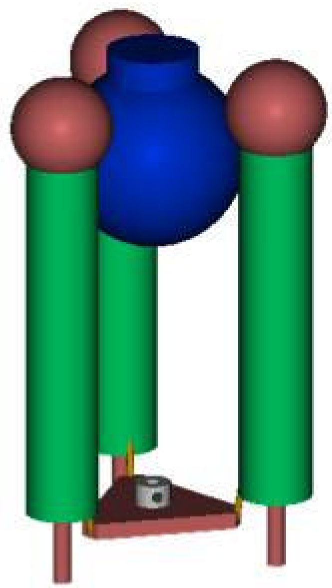


Retention

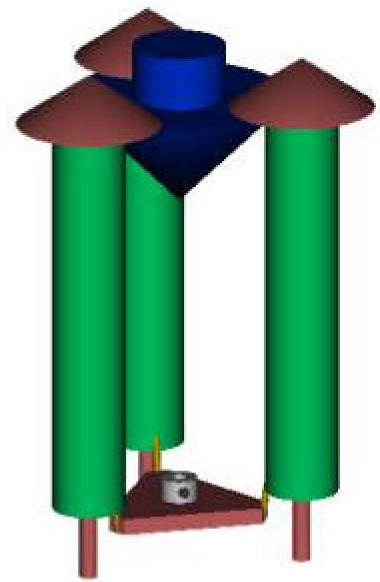




Burred Surfaces



Spherical Ends



Conical Ends

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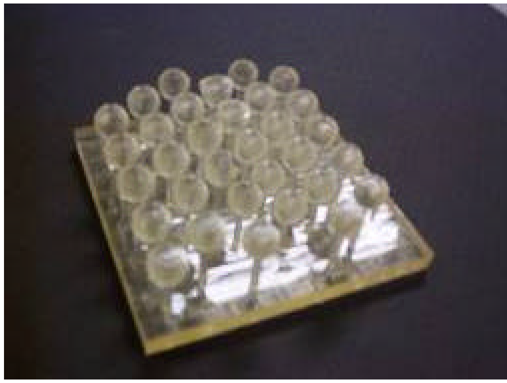
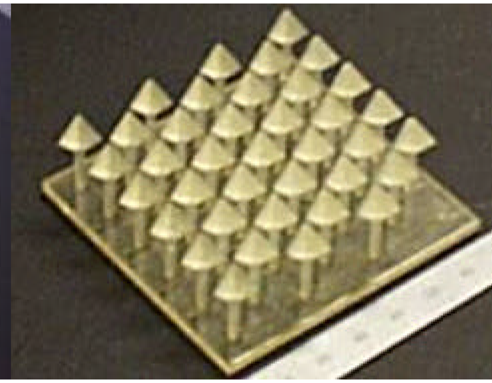
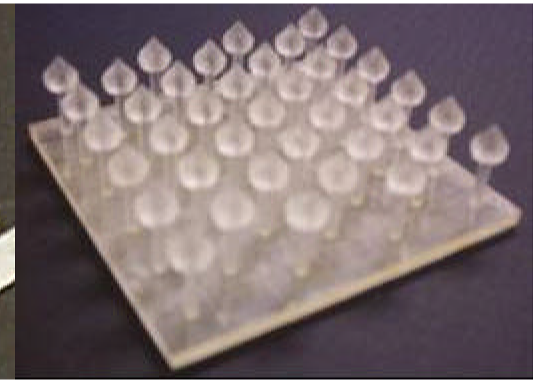
Stereolithography Topology Prototypes



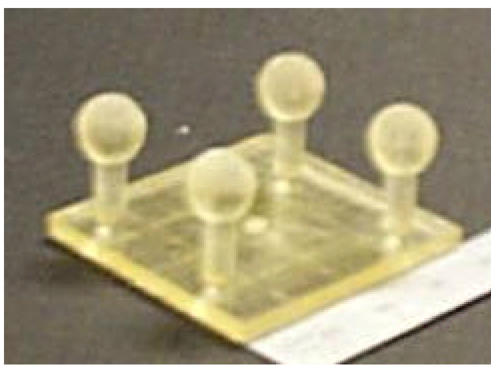
Sphere Prongs



Tetrahedron Prongs



Bulb Prongs



Sphere/Tetrahedron Posts

Bulb Post

Inserted Configuration

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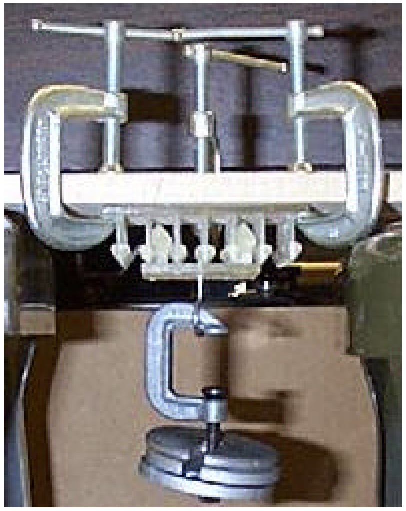
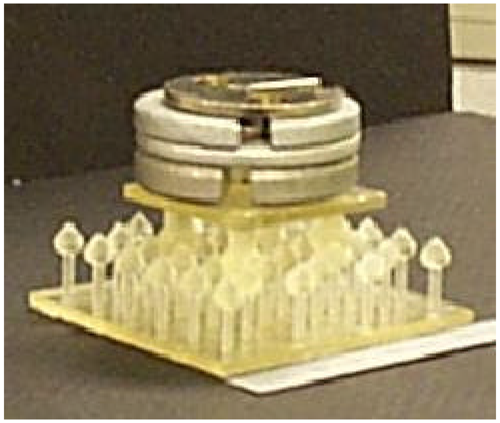
Topology Experimental Study Results

- **Lessons Learned:**
  - <u>Sphere:</u> provides low engagement forces at the cost of reduced retention force
  - <u>Tetrahedron:</u> excellent engagement capabilities but poor retention force
  - <u>Bulb:</u> provides good balance of engagement and retention capabilities



Disengagement



Engagement

	Engagement Force (N)	Disengagement Force (N)
Sphere	4.7	6.9
Tetrahedron	2.9 / 22.6	1.8 / 9.9
Bulb	8.6	10.1

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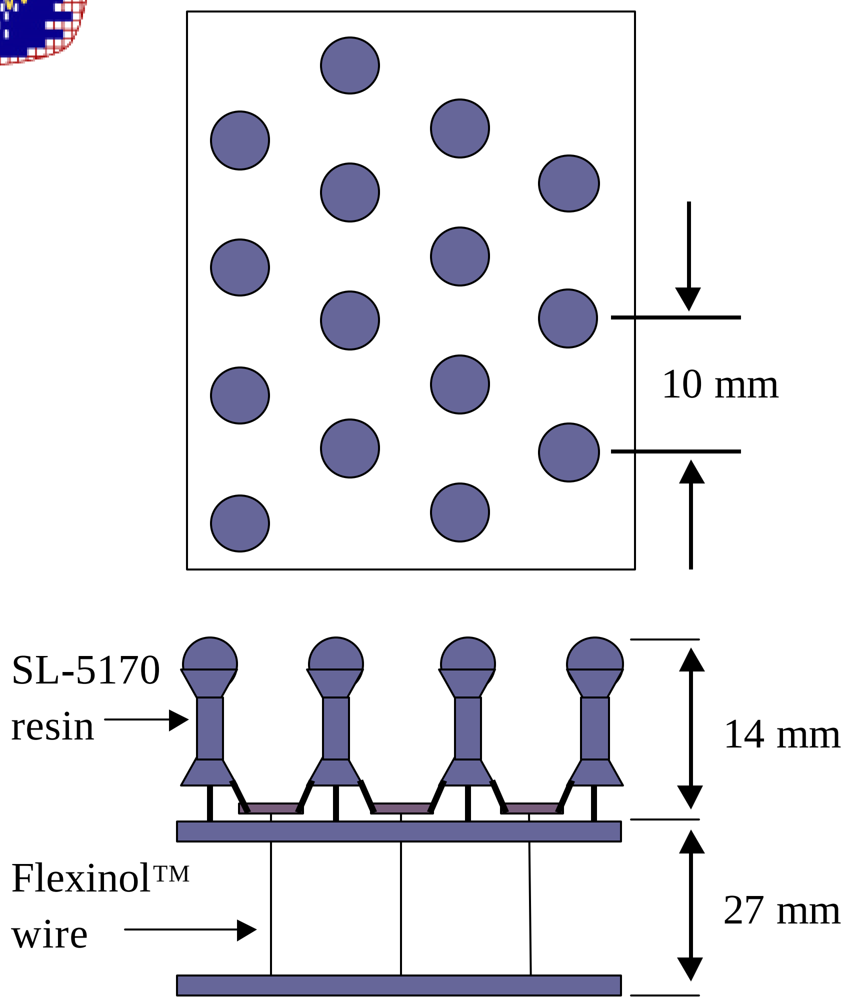
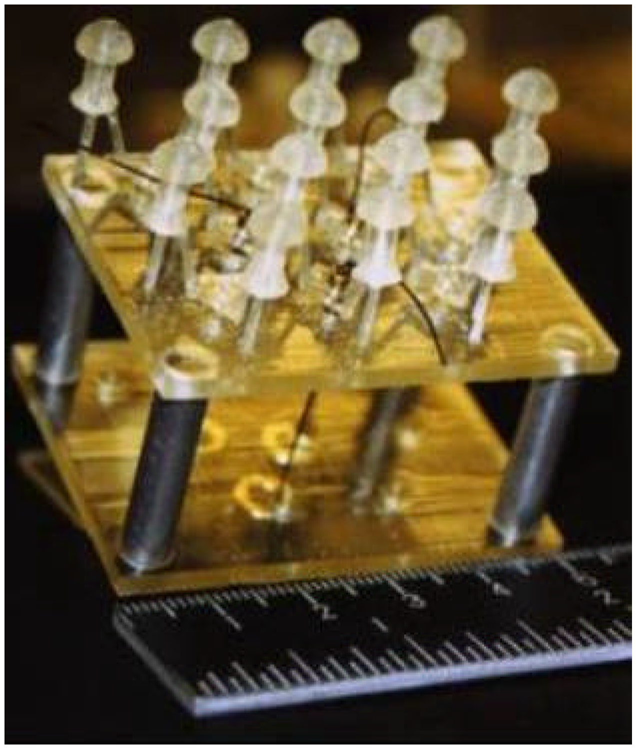
Small-Scale Prototype





Step Size: ~ 6 mm
Linear Speed: 0.6 - 6 mm/s
Input Power (per step): 2.3 W
Demonstrated Translation

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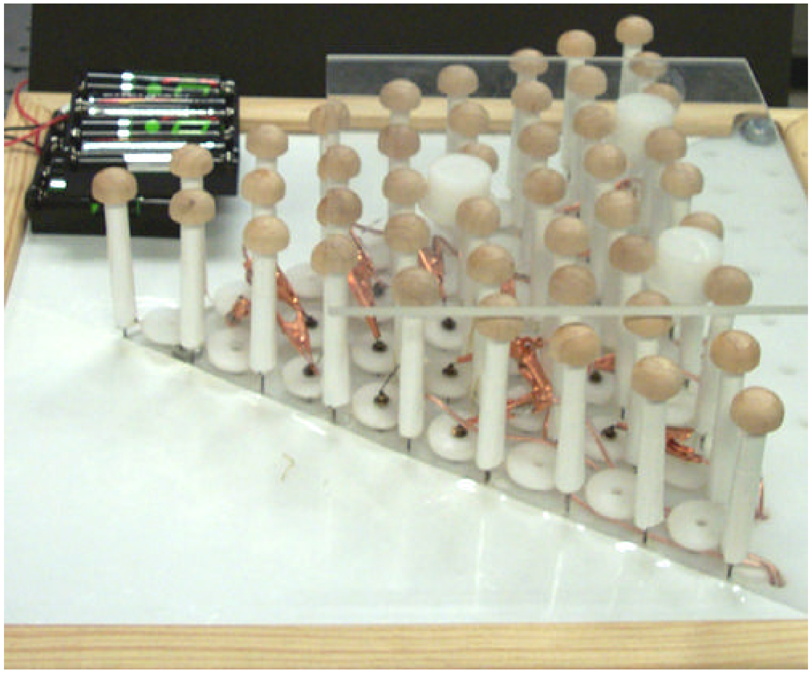
Accomplishments

Initial concept generation

- Several unique concepts were generated
- An active material selection process was performed
- Designs were initially modeled based on buckling loads, actuator force/deflection criteria, power requirements and failure mechanisms
- Down selection to final design with developed evaluation metrics



A simple large-scale proof-of-concept prototype

- Constructed with off-the-shelf components (~ 11x11x14 cm)
- ***In initial tests, prototype demonstrated planar translation***

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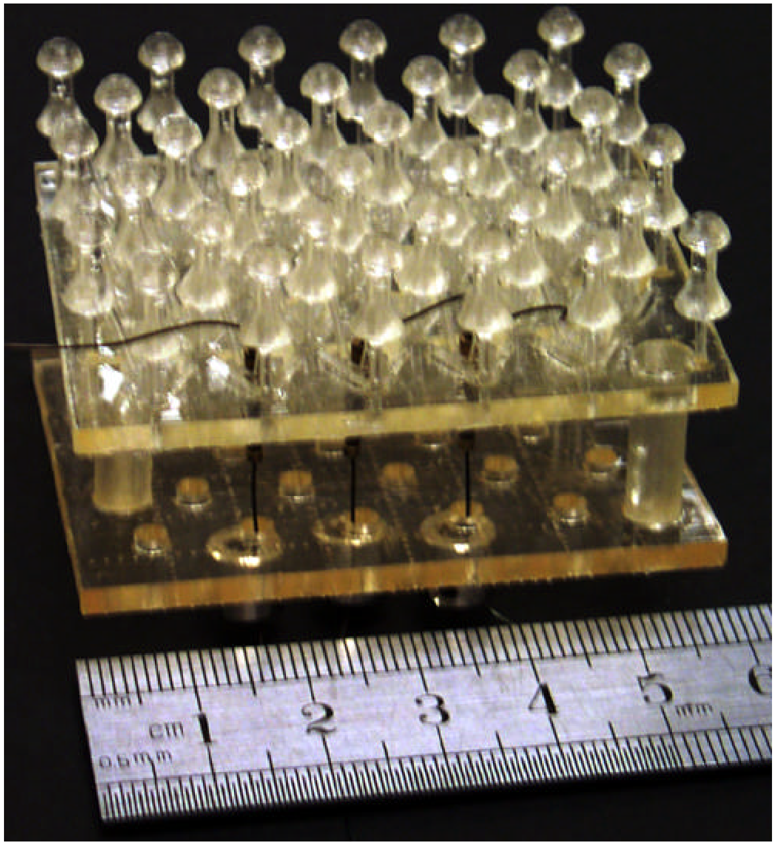
Accomplishments Continued

A topology study was conducted

- Engagement, retention and required translation forces may be tailored independently
- Small changes in the surface finish (burrs) have been demonstrated to significantly increase retention forces



Reduced-scale stereolithography prototypes have been constructed

- Varied engagement and retention forces through connection topology alterations
- One piece flexure mechanism and structural backbone
- ***In initial tests, prototype demonstrated planar translation***

Patent filed and pending

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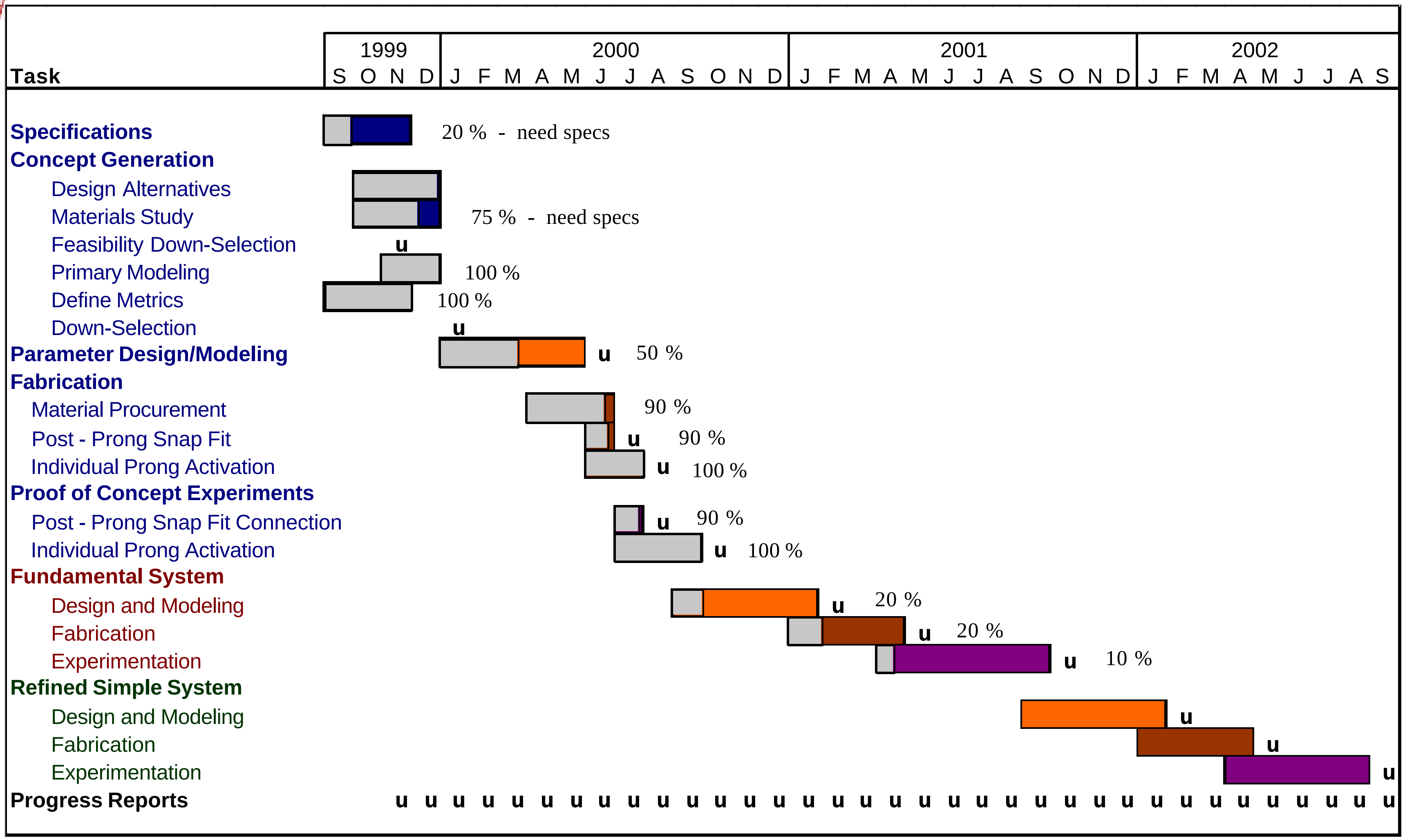
Schedule



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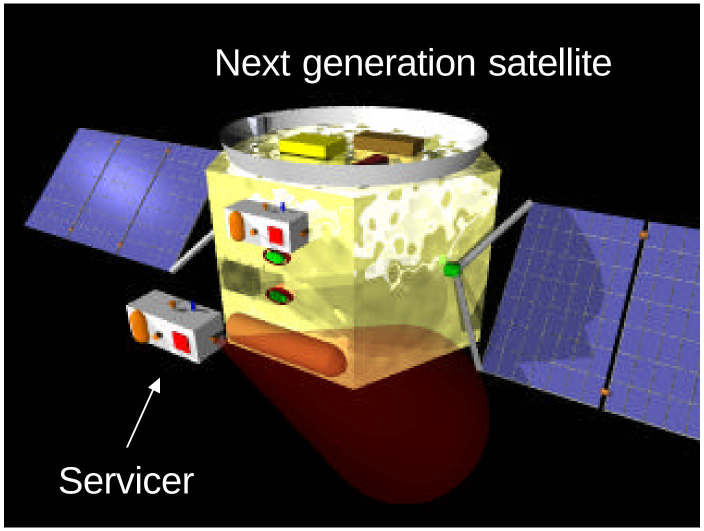
Technology Transfer and Potential Customers

Space Structures

- Preliminary discussions with Honeywell on commercialization and licensing initiated
- XSS-11 is being explored as a possible experimental satellite platform to test servicing capabilities on the experimental satellite
- Potential use for course-accuracy docking on Orbital express to save on guidance and control complexity when plugging in orbital replacement units

Potential Markets

- Manufacturing
  - assembly and precision connections
  - precision shaping and placement
  - fixturing and alignment
  - reconfigurable tooling
- Telecommunications and Optics
  - fiber optic placement, connection, and alignment
  - precision lens/mirror alignment and shape control
- Medicine
  - bio attachments
  - sutures
  - alignment of prosthetics
  - assistive surgical tools



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